Balancing Omni-directional, Multi Surface Skateboard (BOMSS)

System Design and Project Plan

October 13, 2009

Casey Christensen

Harrison Cobb

Misael Marriaga

Table of Contents

System Design 2

Background 3

System Overview 3

Block Diagram 5

Functional Decomposition of Blocks 6

Project Plan 8

Organization and Management 9

Work Breakdown Structure – Fall 2009 10

Work Breakdown Structure – Spring 2010 12

Estimated Costs and Budgeting 13

Gantt Chart – Fall 2009 14

Gantt Chart – Spring 2010 15

Network Diagram – Fall 2009 16

Network Diagram – Spring 2010 17

Appendices 18

Appendix A (Mechanical Drawings) 19

Appendix B (Requirements Specification Document) 23

Appendix C (Data Sheets / Cost Estimates) 29

System Design

Background

Riding a skateboard can be difficult and discouraging to learn. We will create a device that will allow beginners to quickly enjoy being able to ride a skateboard. It will also have a compact design that allows it to be easily maneuvered in an urban environment. The BOMSS will be a skateboard-style, self-balancing vehicle. Basic design consists of a platform for the rider to stand on, with two independently operated wheels fastened centrally to the underside. The operational components will be contained in water and vibration resistant compartments where they will be protected from collisions with foreign objects. These compartments and the components they contain will be easily accessible to the user, while remaining "hidden" within the structure as to not interfere with the user's ability to effectively operate the vehicle. The BOMSS will be an enjoyable recreation vehicle for users of nearly any age that are looking for a unique and inventive new way to spend their time. Its maneuverability and ability to operate efficiently in many different environments will make it stand apart from other similar recreation and transportation vehicles.

System Overview

The design is a two wheeled, self balancing vehicle that provides a dynamic turning radius, meaning that the turning radius is proportional to the velocity of the vehicle, with a near zero turning radius at no forward motion. If the vehicle, for example, it traveling at a rate of 4 m/s, the turning radius will be much greater and therefore more stable than if the vehicle were traveling at a rate of 0.5 m/s, where the radius would be significantly decreased. This will make the vehicle useful and easy to maneuver in an urban environment. The Balancing, Omni-directional, Multi Surface Skateboard (BOMSS) will utilize accelerometers and gyroscopes to sense the angular position of the skateboard with respect to the horizontal plane. This information will then be used as an input in its controls algorithm. The vehicle will be maneuverable in the forward and aft direction, as well as steering left and right.

Angular position and angular rate will be monitored by the accelerometers and angular rate sensors (gyros). These sensors will send a signal to the microcontroller that runs controls algorithm based on the equations of motion of the skateboard-rider system. Once the velocity of the skateboard necessary to maintain the level platform is calculated by the microcontroller, it will send a signal that will adjust the power delivered to the motors to achieve such velocity.

Safety features will include a minimum rider weight and an anti-theft key. Before power is delivered to the system, the rider must insert a removable anti-theft key and then fully depress a mechanical weight sensor. Power is provided by a rechargeable, on-board battery.

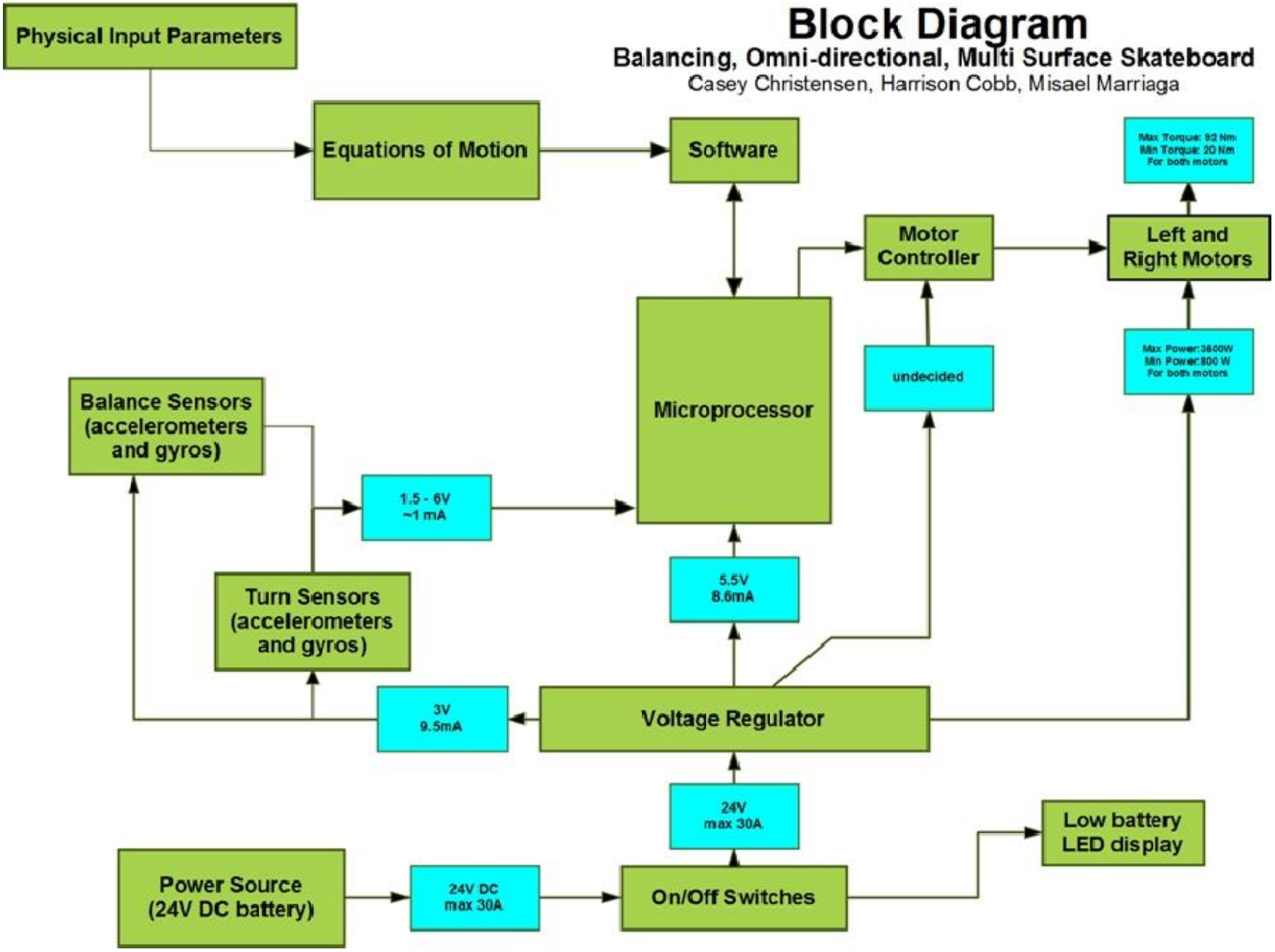
For further detail describing the operation, refer to the requirement specifications document located in Appendix B.

Deliverables for this project will include the self balancing skateboard capable of a runtime of approximate 1 hour, anti-tamper key, user's manual, and all relative schematics, analysis, drawings, and documentation showing test results.

Block Diagram

Balancing, Omni-directional, Multi Surface Skateboard

Casey Christensen, Harrison Cobb, Misael Marriaga



Functional Decomposition of Blocks

Physical Input Parameters: These parameters include the actual mass of the skateboard and its calculated rotational inertia, as well as average estimates of the rider's mass, rotational inertia, and height.

Equations of Motion: Provided with physical input parameters, these equations will be integrated as part of the controls algorithm into the software that enables the board to maintain a level plane.

Balance Sensors: These sensors include an accelerometer and an angular rate sensor (gyroscope). The accelerometers will provide the microcontroller with readings of the component of gravity perpendicular to the skateboard with the purpose of calculating the board's angular position. The angular rate sensors will provide readings on the angular velocity of the skateboard to the microcontroller, which will calculate the direction in which the skateboard is tilting. These calculations will be used to determine the proper adjustments of the motors to keep the skateboard on a level plane. The accelerometer will require a supply of no less than 2.2 V and no more than 3.6 V. The output signal will be no less than 289.5 mV/g and no more than 326.5 mV/g. The accelerometer reads ±4 g. The angular rate sensors will require a supply of no less than -0.3 V and no more than 6.0 V. It will have a typical sensitivity of 2.0mV/°/s.

Turn Sensors: These sensors include an accelerometer and an angular rate sensor (gyroscope). These sensors will perform in the same way as the balance sensors but with the purpose of sensing the angular position and angular velocity of the skateboard about an axis perpendicular to the axle of the wheels and on the horizontal plane. The turn sensors will provide the acquired information to the microcontroller, which will send a signal to adjust the motors to turn. The sensors will be the same as the ones used for balance, though properly arranged to sense turning.

Software: The software is the electrical manifestation of the equations of motion. Using the derived equations along with the collected sensor values, the software will calculate the duty cycles needed for the microprocessor to precisely control the motors for maintaining a level platform as well as maneuvering the skateboard.

Microprocessor: This unit will compile the sensor information and communicate with programmed software. Once the sensor information is collected, the derived equations of motion can be applied through software to calculate the necessary duty cycle, which controls each wheel's motion independently. The microprocessor may require up to four (4) A/D (Analog to Digital) ports for sensor input, and will require multiple ports for output to the motor controller.

Voltage Regulator: The voltage regulator contains hardware to supply various voltages necessary to run the 1) balance and turn sensors, 2) microprocessor, 3) motor controller, and 4) possibly each motor. Preliminary voltages required may include +/- 5V, +12V, and +24V.

Power Source: The chosen power source will be a 24V rechargeable battery, with a capacity rating of at least 12 Ah. Options include SLA, NiMH, and NiCd.

Motor Controller: This unit will accept the signals from the microprocessor and control both the speed and direction of each independent motor.

Left and Right Motors: Motors selected are 350 watt motors. Each motor is independently controlled by the microprocessor via the programmed motor controller. Based on inputs from the accelerometers and angular rate sensors, the controller will drive the motors appropriately to maintain balance as well as produce motion.

Battery Level Display: The battery level display is an LED voltage display typically used in remote controlled aircraft. This will provide the user with instant information on the state of charge of the battery.

On/Off switches: There are two individual On/Off switches, both of which engage/disconnect power from the battery. Note that neither switch will provide any function to the BOMSS unless the aforementioned anti-theft key is securely in place. The first switch is a “main power” push button switch that, when engaged, will allow the BOMSS to be powered and ready for a rider. However, it does not allow for any unauthorized motion or balancing at this point, as the second switch also needs to be engaged for full operation. The second switch is a safety switch that is activated by a specified weight depressing the foot platforms. Without this second switch in place, if the main power button were engaged and the platform were inadvertently brought level without a user being onboard, the BOMSS would begin its balancing operations and could become unsafe. This safety concern required the addition of this second weight sensor switch.

Project Plan

Organization and Management

Casey Christensen – Casey is a senior level mechanical engineering student, and was selected as the team lead for this project. He is responsible for determining mechanical dimensions and materials used in construction, as well as performing finite element analysis of stresses and deformations to eliminate the possibility of a stress related failure of the frame or any other mechanical element. Also, alongside Misael, he will be formulating the equations of motion that will ultimately be used to control the BOMSS. Casey will work with Misael to select an appropriate gear ratio so as to insure little or no undue stress on any particular component. Casey will provide CAD drawings and schematic specification sheets. Throughout the entire project, Casey will be responsible for ensuring that the project is moving at an appropriate rate and that is stays on course.

Harrison Cobb – Harrison is a senior level computer engineering student, with a 70/30% split between electrical engineering and computer science, respectively. He is the sole computer engineer on the project and is responsible for selecting and programming the microprocessor, developing and building circuit boards, and determining appropriate motors and battery. Also, he will be working with Casey and Misael in the general construction of the project. Harrison will provide circuit simulations and a professionally etched circuit board.

Misael Marriaga – Misael is a senior level mechanical engineering student. He is responsible for selecting accelerometers and angular rate sensors (gyros). He is also developing the equations of motion necessary for control and he will perform finite element analysis of stresses and deformations to eliminate the possibility of a stress related failure of the frame or any other related mechanical element. Misael will develop the control system algorithms that will be used and programmed into the microcontroller by Harrison. He will also work with Casey to select an appropriate gear and chain ratio and help build the frame.

The tasks listed above for each engineer are not all inclusive. All members are versatile enough to assist each other in their respective responsibilities; therefore the above task schedule is subject to change. All members are responsible constant documentation of all work completed as well as gathering and presenting their information and progress in the group's bi-weekly presentation of an A3 status report.

Work Breakdown Structure - Fall 2009

Task	Activity	Description	Deliverables / Checkpoints	People	Duration (weeks)	Resources
F1.0	**Requirements Specifications**	Document stating what the project will accomplish in detail	General ideas for the project in written document	C,H,M	4	PC
F2.0	**Overall System Design**	Design overall project in detail	Brainstorming ideas, produce working design	C,H,M	9	PC
F3.0	**Mechanical and Power Analysis**	Calculating equations of motion, stress analysis, and power requirements	Equations of motion, finite element analysis, Electrical Power Analysis	C,H,M	8.5	PC
F3.1	EOM	Calculate EOM of the system	Calculations and derivation	M_1,C_2	1.5	Textbooks
F3.2	Stress Analysis	Finite element analysis of axles and frame	Data from analysis	M_1,C_2	4	PC
F3.3	Torque Requirements	Calculate torque requirements from EOM	Calculations and derivation	M	1	EOM
F3.4	Power Deliverability	Determine power using electrical analysis	Calculations	H	2	Textbooks
F4.0	**Structure Design**	Design the dimensions and materials for housing	Design details, knowledge of technology, CAD drawings	C	1.5	PC
F4.1	Dimensions of Frame	Ensure dimensions are realistic	CAD drawings	C_1,M_2,H_3	1	PC
F4.2	Materials for Construction	Choose lightweight, strong and durable materials	Design details	C	0.5	PC
F5.0	**Power Supply Design**	Battery circuit providing inputs to limiters and circuitry	Design details, knowledge of technology	H	2.5	PC
F5.1	Switches	Choose switch that is easily depressed	Design details, knowledge of technology	H	1	PC
F5.2	Voltage Regulator	Research options	Design details	H	1	PC
F5.3	Low Battery LED Display	Research Options	Knowledge of technology	H_1,C_2	0.5	PC
F6.0	**Inertial Measurement Unit Interfacing Design**	Accelerometer and angular rate sensors that provide angular position for the control system	Design details, knowledge of technology	M	2.5	PC
F6.1	Research	Determine possible components of unit	Knowledge of technology	M	2.5	PC

Work Breakdown Structure - Fall 2009 (continued)

F7.0	**Parts Selection**	Make final decisions on parts to be used	Order parts needed and documentation of all purchases	C,H,M	10	PC
F7.1	Motors	Choose by power and torque requirements	Knowledge of technology	M	1.5	PC
F7.2	Axle and Wheel Assembly	Choose materials that will hold specified weights	Design details	C_1,M_2	1	PC
F7.3	Gearing and Chains	Choose gears and chains according to ratio and torque requirements	Design details	C_1,M_2	2	PC
F7.4	Microcontroller	Find board that is sufficient for all components	Knowledge of technology	H	3	PC
F7.5	Sensors	Choose number of axes and sensibility	Knowledge of technology	M1	1.5	PC
F7.6	Battery	Choose size and power deliverability determined by motor requirements	Knowledge of technology	C,M,H	1	PC
F8.0	**System Analysis**	Analyze entire design to test for functionality	Test dimensions, power requirements, torque requirements, data analysis	C,H,M	4	PC, SolidWorks, AutoCAD, MultiSim
F9.0	**System Design and Project Plan**	Breakdown of design and build process with detailed scheduling	Report, visual aided presentation	C,H,M	2	PC
F9.1	Report	Write detailed report regarding the ideas mentioned above	Report	C_1,H_2,M_2	0.5	PC
F9.2	Presentation	Present ideas to faculty	PowerPoint	C,H,M	0.5	PC
F10.0	**Final Design**	Finalize the design and no more changes can be made past this point	Report, visual aided presentation	C,H,M	2	PC
F10.1	Report	Write detailed report regarding the ideas mentioned above	Report	C_1,H_2,M_2	0.5	PC
F10.2	Presentation	Present ideas to faculty	PowerPoint	C,H,M	0.5	PC
C1.0	**Documentation**	Continue to log all work into laboratory books	Sufficient documentation to depict project progress	C,H,M	17	PC, Notebooks
C2.0	**Project Management**	Oversee project progress and keep the project on course	Smoothly operating project	C	17	Class Literature

Work Breakdown Structure - Spring 2010

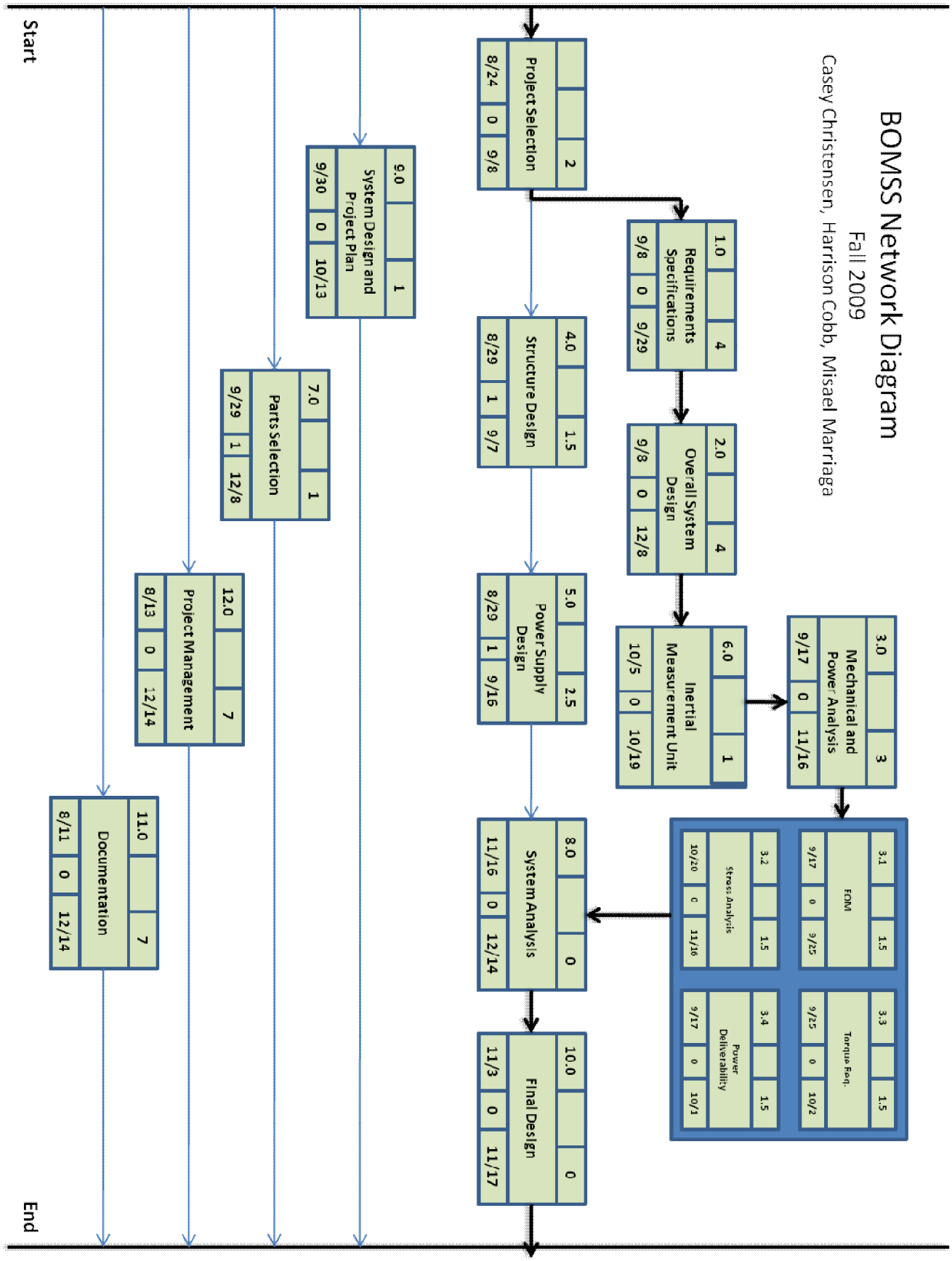
Task	Activity	Description	Deliverables / Checkpoints	People	Duration (weeks)	Resources
S1.0	**Parts Assembly and Testing**	Assemble all parts and verify they work correctly	Working parts, test data	C,H,M	10	Various Equipment
S1.1	Build Structure	Build housing for all components	Finished device housing	C_1,M_2	3	Metal and plastics, shop
S1.2	Compile Circuitry	Create and test circuitry	Finished main circuitry, test data	H	4	Evaluation board, oscilloscopes
S1.3	Board Etching	Design and order circuit boards	Professionally made circuit board	H	4	Outsourcing
S1.4	Sensors	Build circuits and verify that sensors operate according to specifications	Proper sensor readings, test data	M_1,H_2	2	Evaluation board, oscilloscope
S1.5	Power Supply	Mount battery to structure and attach to circuitry	Adequate power supply	H_1,C_2,M_2	2	Oscilloscope
S1.6	Microprocessor	Build circuitry and verify correct operation of device	Working device, test data	H	2	PC, evaluation board
S1.7	Motors	Connect motors to power and verify correct operation and functionality	Functional motors, test data	C	0.5	Power supply, oscilloscope
S1.8	Gears and chains	Attach gears and chains and verify correct operation	Smooth operation, test data	C_1,M_2	0.75	Power equipment
S1.9	Wheels	Attach wheels to structure and verify mounting to be stable	Attached wheel to shaft, free movement, no binding, functional component	C	0.5	Power equipment
S2.0	**Programming**	Write code for microprocessor and download code to the device	Operational code, test data	H	10	PC, evaluation board
S3.0	**Project Status Presentation**	Presentation of the project's status	Report, visual aided presentation	C,H,M	0.5	PC
S4.0	**System Integration**	Compile all individual components to build the prototype	Assemble product, test data	C,H,M	3	Work shop

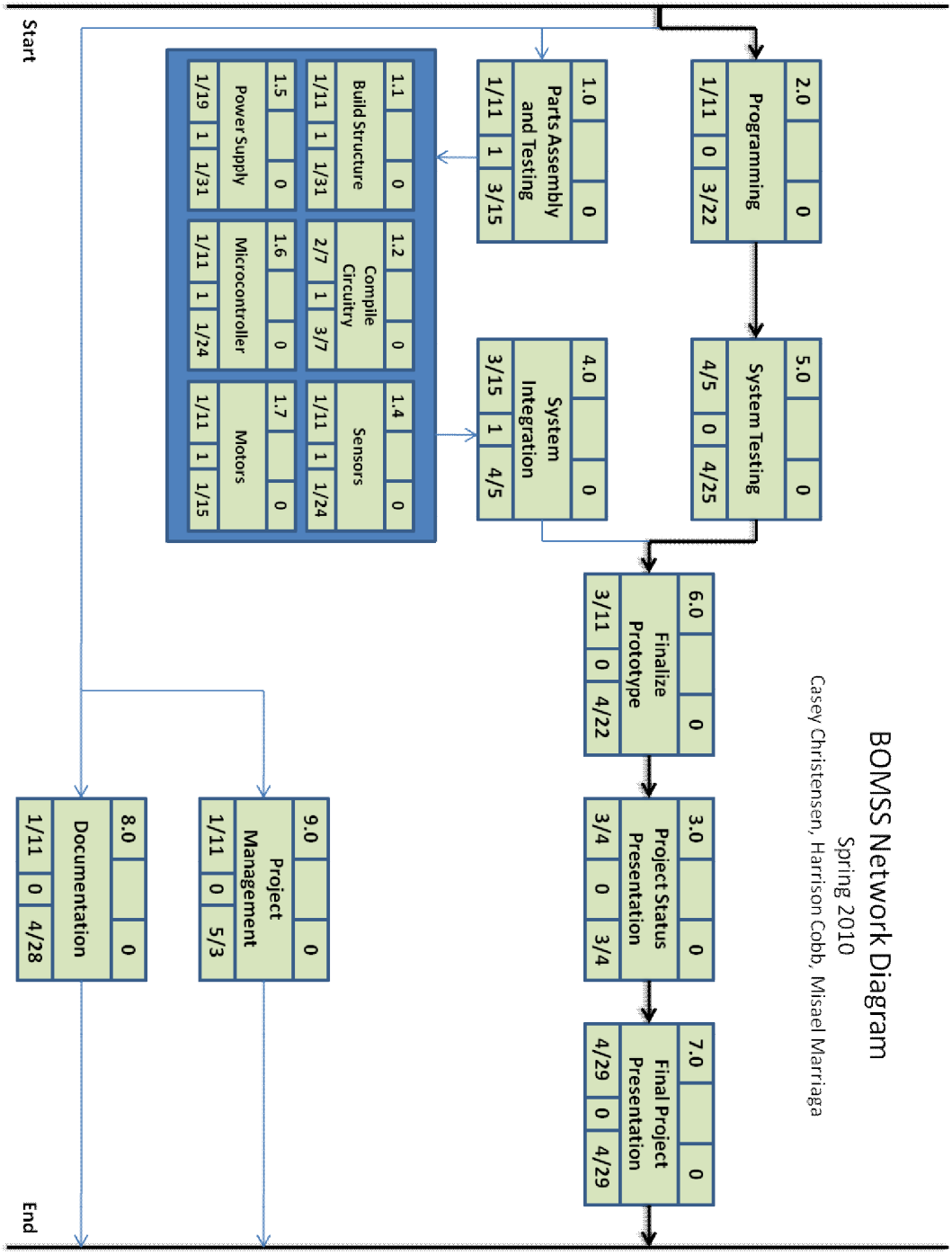
Work Breakdown Structure - Spring 2010 (Cont.)

S5.0	**System Testing**	Test the prototype per specifications requirements document	Test data	C,H,M	3	PC, evaluation board, oscilloscope
S6.0	**Finalize Prototype**	Verify correct operation and prepare for final demonstration	Working prototype	C,H,M	6	PC, evaluation board, oscilloscope
S7.0	**Final Project Presentation**	Present the prototype	Report, visual aids, prototype	C,H,M	0.5	PC
C1.0	**Documentation**	Continue logging all research and work done	Sufficient documentation to depict project progress	C,H,M	15	PC, Notebooks
C2.0	**Project Management**	Oversee project progress and keep the project on course	Smoothly operating project	C	16	Class Literature

Estimated Costs and Budgeting

Items	Costs	Possible Vendor	Date of Cost Estimate
Main Drive Wheels (2), front wheels (2)	$20.00	Bike City, Searcy AR	10/3/2009
Lexan Sheeting (12)	$4.39 sq. ft	estreetplastics.com	10/9/2009
Center axle	$12.51	mcmastercar.com	10/3/2009
Bar stock for "safety" wheels	$4.54	mcmastercar.com	10/3/2009
68 Tooth Rear Sprocket For #25 Chain for main shaft (2)	$17.95 each	electricscooterparts.com	10/4/2009
Sprockets for motor shaft (2)	On motor	electricscooterparts.com	10/3/2009
#25 Chain With Master Link (2)	$8.40 each	electricscooterparts.com	10/3/2009
Dual Axis Gyro	$14.95	sparkfun.com	10/3/2009
Accelerometers (2)	Samples ordered	freescale.com	10/1/2009
350W motor (2)	$50.00 each	electricscooterparts.com	10/3/2009
Microprocessor	~ $100.00		
Lead acid battery	$100.00	advancedbattery.com	10/3/2009
Pro-Etched Circuit Board	~ $60.00	piclist.com	10/4/2009
Contingencies & Misc.	~ $332.27		
Total Estimated Cost	$850.00		


BOMSS Network Diagram
Fall 2009
Casey Christensen, Harrison Cobb, Misael Marriaga
Start
End
Project Selection
8/24 | 0 | 9/8 | 2
Requirements Specifications
9/8 | 0 | 9/29 | 1.0 | 4
Overall System Design
9/8 | 0 | 12/8 | 2.0 | 4
Inertial Measurement Unit
10/5 | 0 | 10/19 | 6.0 | 1
Mechanical and Power Analysis
9/17 | 0 | 11/16 | 3.0 | 3
FOM
9/17 | 0 | 9/25 | 3.1 | 1.5
Torque Req.
9/25 | 0 | 10/2 | 3.3 | 1.5
Stress Analysis
10/20 | 0 | 11/16 | 3.2 | 1.5
Power Deliverability
9/17 | 0 | 10/1 | 3.4 | 1.5
Structure Design
8/29 | 1 | 9/7 | 4.0 | 1.5
Power Supply Design
8/29 | 1 | 9/16 | 5.0 | 2.5
System Analysis
11/16 | 0 | 12/14 | 8.0 | 0
Final Design
11/3 | 0 | 11/17 | 10.0 | 0
System Design and Project Plan
9/30 | 0 | 10/13 | 9.0 | 1
Parts Selection
9/29 | 1 | 12/8 | 7.0 | 1
Project Management
8/13 | 0 | 12/14 | 12.0 | 7
Documentation
8/11 | 0 | 12/14 | 11.0 | 7


BOMSS Network Diagram
Spring 2010
Casey Christensen, Harrison Cobb, Misael Marriaga
Start
End
2.0
Programming
1/11
0
3/22
1.0
Parts Assembly and Testing
1/11
1
3/15
5.0
System Testing
4/5
0
4/25
4.0
System Integration
3/15
1
4/5
6.0
Finalize Prototype
3/11
0
4/22
3.0
Project Status Presentation
3/4
0
3/4
7.0
Final Project Presentation
4/29
0
4/29
1.1
Build Structure
1/11
1
1/31
1.2
Compile Circuitry
2/7
1
3/7
1.4
Sensors
1/11
1
1/24
1.5
Power Supply
1/19
1
1/31
1.6
Microcontroller
1/11
1
1/24
1.7
Motors
1/11
1
1/15
9.0
Project Management
1/11
0
5/3
8.0
Documentation
1/11
0
4/28

Appendices

Appendix A

(Mechanical Drawings)

****NOTE****

The Dimensions that were chosen for the technical drawings are specific to this design only. The limits on size were dependent on the battery size, motor footprint, estimated circuit board size, wheel diameter, and foot platform area. The dimensions are subject to change, but as drawn, all components will fit within the frame with no complications.

Appendix B

(Requirements Specification Document)

Balancing Omni-directional, Multi Surface Skateboard (BOMSS)

Requirements Specification

Harrison Cobb, Misael Marriaga, Casey Christensen

Overview:

Riding a skateboard can be difficult and discouraging to learn. We plan to create a device that has an easy learning curve, allowing beginners to quickly enjoy being able to ride a skateboard. It will also have a compact design that allows it to be easily maneuvered in an urban environment. The BOMSS will be a skateboard-style, self-balancing vehicle. Basic design consists of a platform for the rider to stand on, with two independently operated wheels fastened centrally to the underside. The operational components will be contained in water and vibration resistant compartments with easy accessibility to the user, clear of any interference, and protected from collisions with foreign objects. The BOMSS will be a desirable alternative to traditional styles of transportation.

Operation:

Before operation of the BOMSS, a push button switch for the main power (Figure 1) must be "ON" for operation. This will be incorporated into the vehicle's platform and easily accessible to the rider's foot. Until the power switch is "ON" the vehicle will remain powerless.

Figure 1

Figure 1: Position A shows the "ON" position of the switch. Position B shows the "OFF" orientation of the push button switch. For ease and safety, the "OFF" position of the switch was oriented in the compressed position so only one motion would be required to initiate power shutdown.

The BOMSS will then provide a safe mounting technique for the user. The start-up sequence consists of two stages, both dependent on the other:

1) The BOMSS will mechanically sense the weight of a rider on the platform, who must weigh no less than 20kg (44lbs)

2) The platform must be brought level with the ground

Once both criteria are met, the BOMSS will immediately power the onboard motors and maintain a level plane, which is how the rider manipulates movement. Upon leaning in either the forward or backward direction, the skateboard will roll in the direction of tilt. In this manner the skateboard can be moved in a straight path. Upon putting pressure on the toes or heels, the rider can alter the motion of the skateboard in the left or right direction. When the user is ready to get off the vehicle, he/she will come to a complete stop before depressing the push button switch, which will turn the main circuit board "OFF", causing a complete power down.

As an added safety feature, removing weight from the platform will shut down power to the motors. To re-power the vehicle, remount and bring the platform level.

As a precaution against theft or unauthorized use, a removable, anti-tamper key will be included. This key must be inserted into its appropriate slot for the BOMSS to operate. Without this key, there is no way to operate the BOMSS.

Deliverables:

1. User's manual
2. Self balancing skateboard with anti-tamper key
3. CAD drawings, electronic schematics, 3D views and analyses
4. Code and flowcharts
5. Report of testing
6. Final report

Technical Requirements:

1. The BOMSS will maintain a maximum speed of no less than 4 m/s (13 ft/s) and no more than 10m/s (33 ft/s) for safety concerns.
2. The BOMSS will be powered for a runtime of no less than 60 minutes at 30% maximum speed.
3. A turning radius of no greater than 1mx1m (3ftx3ft) at zero forward motion.
4. The BOMSS will have a low battery indicator light (cutoff voltage to be determined).
5. The BOMSS will be capable of carrying a 91kg (200lbs) adult over dense materials such as pavement and concrete, on both a flat and inclined plane.
6. The BOMSS will weigh no more than 23kg (51 lbs).

Testing Plan:

To ensure proper operation, the following tests will be conducted:

Run Time Test:

To test run time, the BOMSS will be required to maintain operation for a total time of approximately sixty (60) minutes. The rider will weigh between 91 and 100 kg (200-220lbs) and will be required to maneuver a predetermined course (refer to Figure 2) around the Harding University campus containing level planes, inclines, and declines over a multitude of surfaces. Riding times can be discontinuous, but a total time of sixty (60) minutes must be summed at an average of 30% of the maximum speed before the battery is recharged.

Figure 2

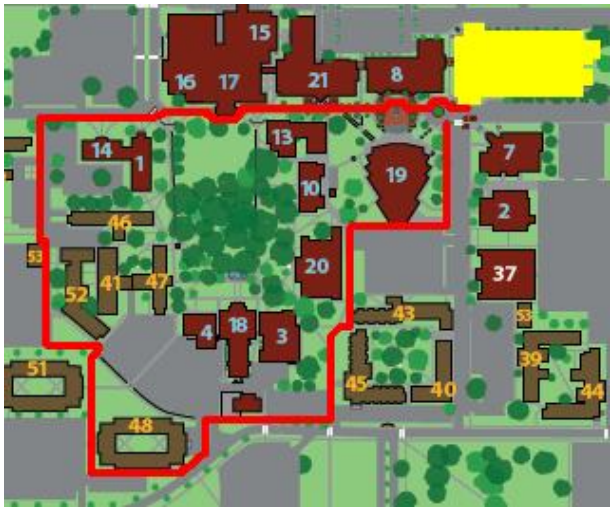


Figure 2: The course the BOMSS will be required to navigate during the test period is indicated in red. The starting and ending place is the Pryor-England Science Center highlighted in yellow. The BOMSS will complete the course at least once to demonstrate its ability to operate in varying surfaces. Care was taken in determining the course as to not encounter any dangerous traffic or intersections and place the tester in harm.

Minimum Speed Test:

To test the maximum speed, the BOMSS will be mounted, then proven to travel a measured distance in a given amount of time. A stopwatch will provide an adequate amount of accuracy. The distance will be forty (40) meters on a flat, asphalt or concrete surface. Time to travel this distance must be between four (4) and ten (10) seconds.

Turning Radius Test:

To test turning radius, only a maximum turning radius will be required. The skateboard will be placed inside a taped-off square of one (1) meter by one (1) meter, and then mounted. A satisfactory test will be if the skateboard can be maneuvered a full 360° without leaving the taped square.

Draft User's Manual:

Initial setup:

1. Connect the battery. To connect a battery, insert the battery into the appropriate tray in the vehicle and attach the positive (+) and negative (-) leads to their respective cables.

   ***NOTE*: Use caution when connecting the batteries to the circuitry in the vehicle. Reversing the positive and negative leads can cause damage to the batteries and circuit boards.**

2. Charging the battery will require a battery charger (not supplied) for the chosen battery. Batteries should be charged for the first time according to the battery maintenance sheet provided, and then as necessary following first use.

Operation:

1. Ensure the anti-tamper key is in place as the vehicle will not be operational until this is inserted into the appropriate slot.

2. Set the BOMSS main push button switch to the "ON" position and mount the platform. Bringing the base level to the floor immediately initiates the self-balancing algorithms. The vehicle is now operational and will react to all movements.

3. To move forwards or backwards, lean body in the desired direction of travel. To arrest motion, return to level plane. Turning requires pressure with either the heels or toes, depending on the desired direction of turn. To stop turn, eliminate edge pressure.

4. Dismount by depressing the “OFF” button on the base. This completely removes power. Also, the skateboard has a safety feature that immediately halts power to the motors if a loss of weight on the platform is sensed; this is useful in the event that the rider falls from the board.

Storage:

1. Set main power push button switch to “OFF”.
2. Store in a cool, dry place.
3. Battery maintenance is supplied in the user’s manual.

Appendix C

(Data Sheets / Cost Estimates)